Release of E. coli D21g with Transients in Water Content

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Introduction

The vadose zone is an important barrier to protect groundwater from pathogenic microorganisms and other colloids that can pose a threat to the public health. Transients in water content triggered by infiltration and drainage events, evapotranspiration, and water table fluctuations are very common in the vadose zone, which have been demonstrated to mobilize retained microorganisms and to promote their transport in the vadose zone (Cheng et al., 2009; Zhuang et al., 2009). However, there is no consensus on the relative importance of drainage and imbibition events on microorganism release (Lazouskaya et al., 2011; Zhang et al., 2012).

Objectives

To systematically study the release of *Escherichia coli* D21g during imbibition, during drainage, and from during cycles of drainage and imbibition under various solution chemistry conditions;

To investigate the efficiency of cell release for various amounts of drainage and imbibition, and the combined influence of transients in saturation and solution IS on release.

Materials and Methods

Ottawa (quartz) sand with a median grain size (d_{50}) of 120 μm was used as the porous media in the column experiments. *Escherichia coli* D21g , a Gram-negative, nonmotile bacterial strain, was employed in the transport experiments.

Around 2 pore volumes of a selected NaCl solution was flushed through the column to achieve steady state flow (saturated/unsaturated), and to allow the sand to equilibrate with the solution. Saturated and unsaturated transport experiments were initiated by injecting about two pore volumes of cell suspension (Phase 1) and then eluting NaCl solution with the same IS (Phase 2) to the column top at a steady-state flow until no significant concentration of bacteria was detected. Various drainage and/or imbibition conditions were implemented in the column (Phase 3) by maintaining a negative pressure at the bottom with no flow at the top boundary, and by initiating or increasing the flow rate at the top of the column. The sand column was drained to different levels by adjusting the height of the hanging water column. The level of imbibition was controlled by the flow rate. The imbibition process was considered finished when steady-state flow was reached and the concentration in the effluent went down back to background levels.

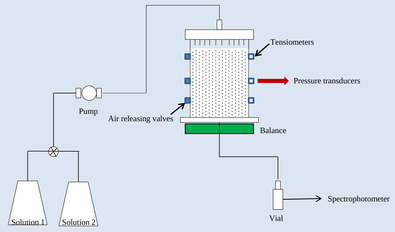


Figure 1. A schematic of the column setup that was employed in the transport and transient release experiments.

Results

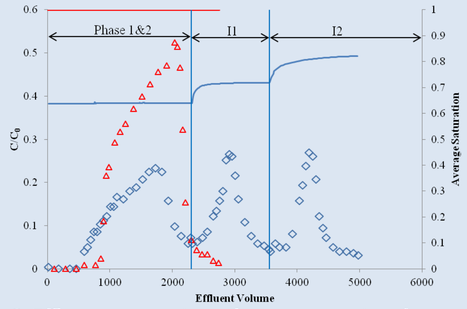


Figure 2. Effluent concentration and average saturation of unsatured transport experiment and following two imbibition sequences (blue), and saturated transport experiment (red) when the IS=5 mM. The mass recovered was 42% for saturated transport experiment, and 41.2% for unsaturated transport and release experiment.

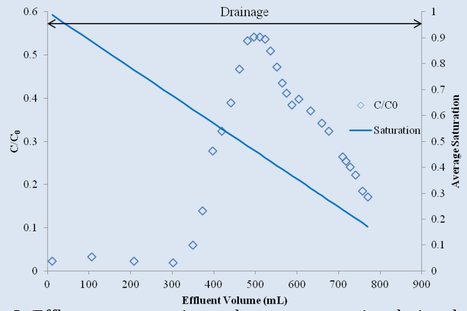


Figure 3. Effluent concentration and average saturation during drainage when the IS=5 mM after saturated transport experiment.

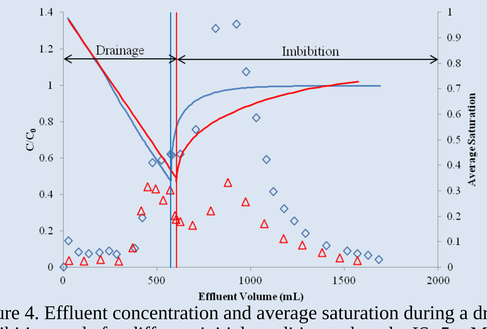


Figure 4. Effluent concentration and average saturation during a drainage and imbibition cycle for different initial conditions when the IS=5 mM. Short (red) and long (blue) input pulse durations (1.5 and 3.1 PVs) were employed during Phase 1 at saturated conditions to obtain different initial conditions.

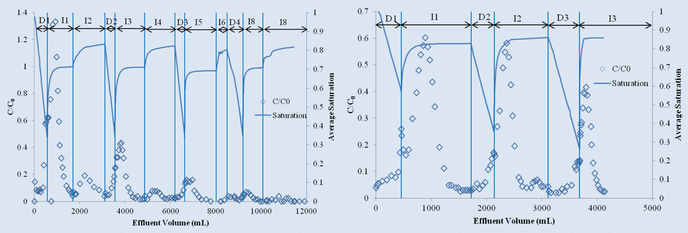
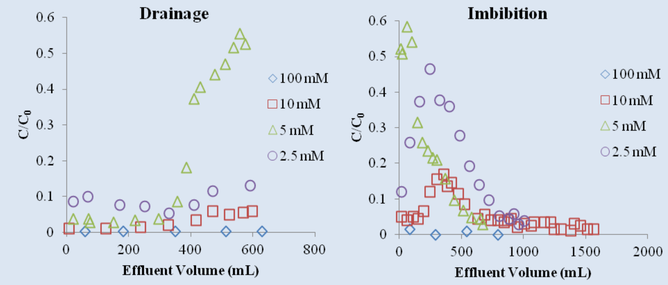


Figure 5. Effluent concentration and average saturation during repeated cycles of similar amounts of water drainage and imbibition (left) or three continuous drainage and imbibition cycles when the column was successively drained to lower water saturations of 0.57, 0.36, and 0.27 by lowering the bottom boundary pressure after saturated transport experiment when the solution IS=5 mM. D# and I# denote the drainage and imbibition number (#), respectively.



Fgiure 6. Effluent concentration during drainage (left) and imbibition (right) after saturated transport experiment when the solution IS=100, 10, 5, and 2.5 mM (Phases 1, 2, and 3).

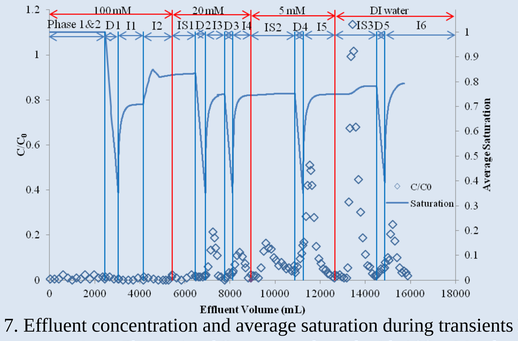


Figure 7. Effluent concentration and average saturation during transients in solution IS and water saturation. Phases 1and 2 were conducted with 100 mM solutions under saturated condition. Phase 3 was conducted by successively lowering the solution IS from 100, to 20, to 5, to 0 mM, and initiating drainage and imbibition cycle(s) as indicated in the figure. D#, I#, and IS# denote the drainage, imbibition, and IS number (#), respectively.

Conclusion

Imbibition efficiently released cells from the air-water interface (AWI) that were initially retained under steady-state unsaturated conditions by expansion of water films and destruction of the AWI. Conversely, significant release and transport of cells during drainage only occurred below a critical water saturation (water film thickness). In this case, a fraction of the cells that were initially retained on the solid-water interface (SWI) partitioned into the mobile aqueous phase and the AWI as the receding water film thickness decreased during drainage. The efficiency of cell release from the SWI during drainage was much less than for the AWI during imbibition. Cycles of drainage and imbibition removed cells from the SWI and the AWI, respectively. However, the peak concentration and amount of cells that were released increased with the number of retained cells and the amount of drainage and imbibition, and decreased with the number of drainage and imbibition cycles. Release of cells during drainage and imbibition was found to be more pronounced in the presence of a weak secondary minimum when the ionic strength (IS) was 5 mM NaCl. Increases in the solution IS decreased the influence of water transients on release, especially during drainage.

References

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